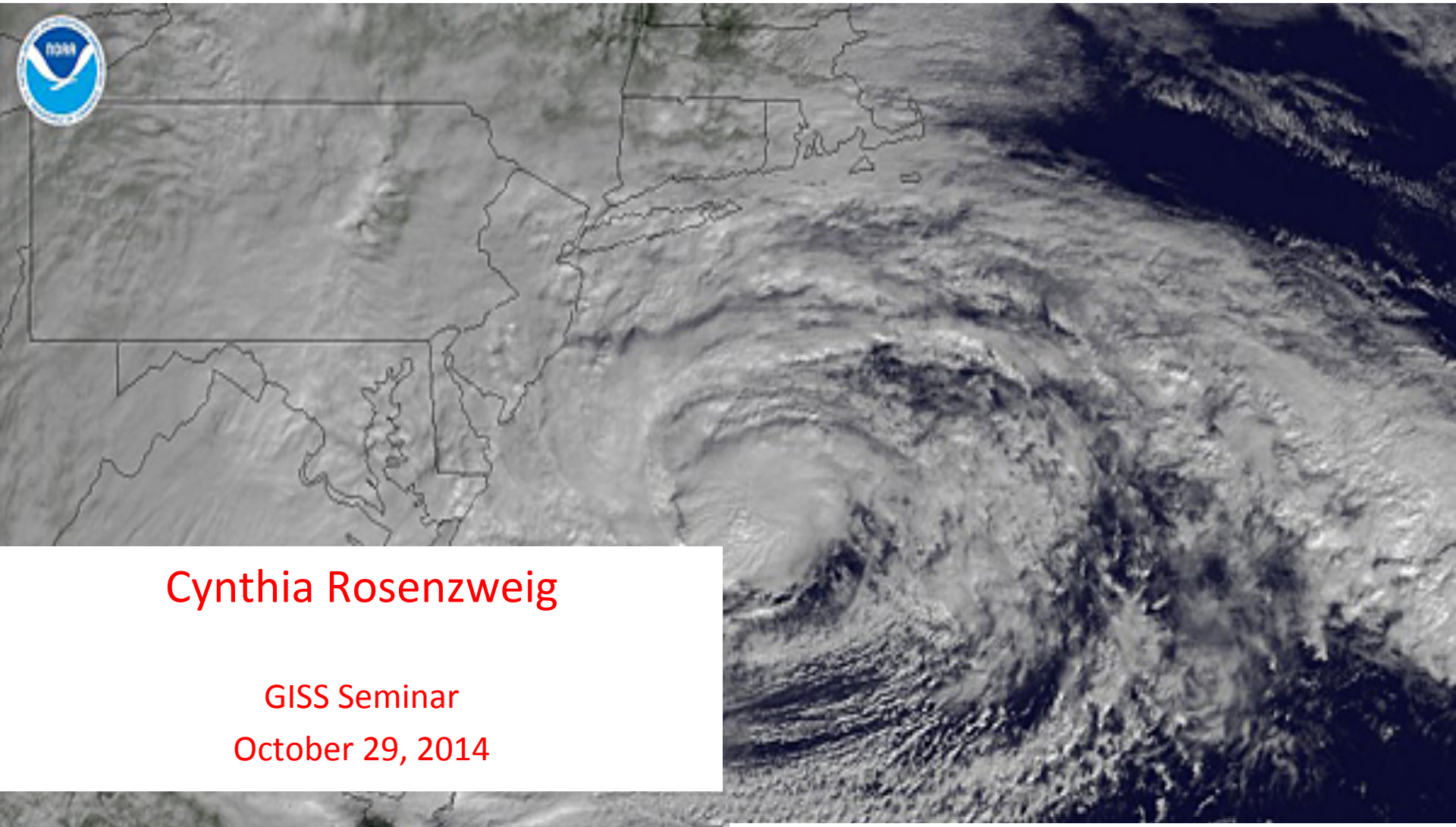
Hurricane Sandy in New York City

Lessons Learned



Cynthia Rosenzweig

GISS Seminar

October 29, 2014

NOAA GOES 13 Satellite, Monday, October 29, 2012

Thanks to GISS/CCSR Impacts Group, NPCC,and CCRUN

Some Lessons Learned . . .

1. Characterizing risk of major storms is a challenge

2. Hurricane Sandy grounded, reinforced, and motivated expansion of the NYC flexible adaptation approach

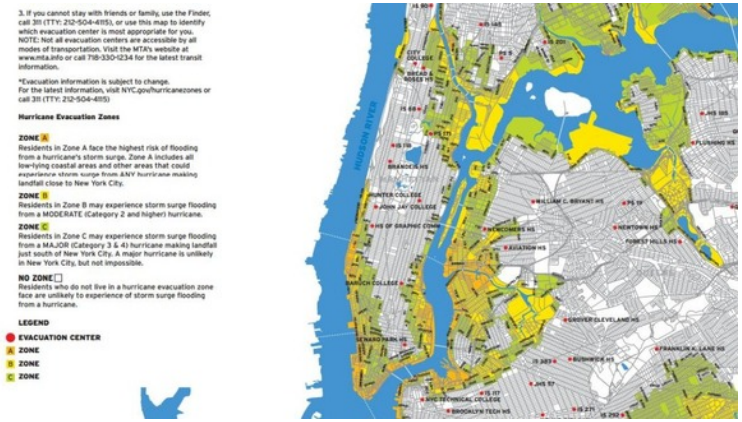
3. Federal regulations balkanized responses: 'The Tale of Two States and One City'

4. Federal, state, and municipal agencies need to coordinate on climate change scenarios

5. Having 'Science in place . . . Science in time' is critical

Hurricane Sandy as 'Tipping Point'

Hurricane Sandy Immediate Preparations



New York City issued mandatory evacuation of Zone A on October 28, 2012

Out-of-state utility crews brought in before the storm

MTA closed down operations, moved rolling stock, and boarded and placed sandbags at subway entrances to protect against flooding

GISS Closes

Re: [giss-people-l] Sandy Columbia x

Ruedy, Reto A. (GISS-611.0)[TRINNOVIM, LLC] <reto.a.ruedy@nasa.gov> 10/29/12

to giss-people-l

GISS will be officially closed tomorrow; no decision has been made about Wednesday.

All windows are closed and printers were shut down. People currently at GISS are advised to leave early.

Thank you for your concern and cooperation,

Reto

Reto A. Ruedy
Project Manager
NASA Goddard Institute for Space Studies
Trinnovim, LLC
2880 Broadway, Rm. 201A, New York, NY 10025
ph: 212-678-5541; email:reto.a.ruedy@nasa.gov

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WWUS71 KOKX 291617
NPWOKX

URGENT - WEATHER MESSAGE
NATIONAL WEATHER SERVICE NEW YORK NY
1217 PM EDT MON OCT 29 2012

...HURRICANE FORCE WIND GUSTS THIS AFTERNOON AND EVENING...
```

Sent at 11:02 AM, 10/29/12

A Few Hours Later . . .

Explosion at a substation on East 14th Street darkened most of Manhattan south of 34th Street.

Power remained on in Battery Park City, as Con-Ed did not shut service as network is on higher ground. More recent construction in Battery Park City provided buildings with generators and moved equipment to higher floors.

~9:00 PM, 10/29/12

New York Magazine, November 2 2012

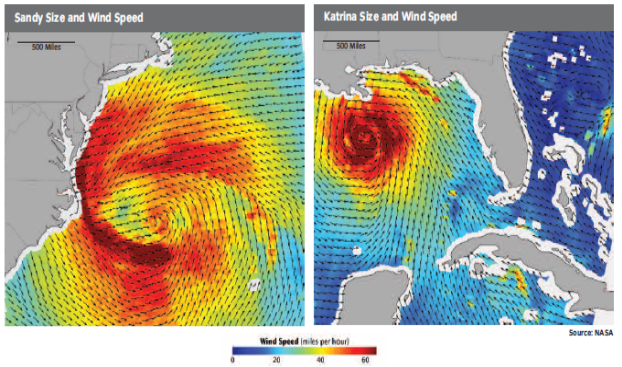
Despite Advanced Forecasts and Preparations . . .

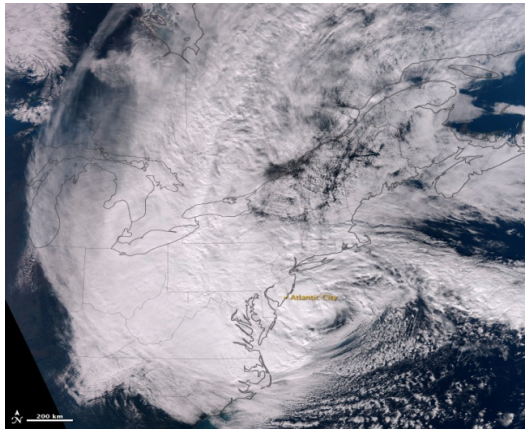
- 44 deaths in NYC, 80% from drowning
- Major flooding 7 subway lines under East River, 3 tunnels closed
- 90,000 buildings in the inundation zone
- ~2 million without power
- *Unforeseen impacts* include gas shortages, hospital evacuations, and fires
- ~$19 billion in damage in NYC

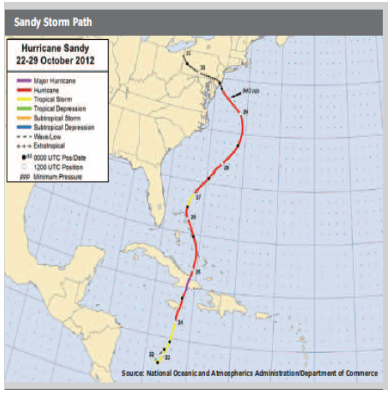
South Ferry Subway Station, Manhattan
December 12, 2012
Source: D. Bader

Hurricane Sandy

- Sandy followed an **unusual storm track,** turning sharply west just as it was reaching another peak of intensity
- **Tropical-storm-force winds (39 to 73 mph) extended 1,000 miles** from end to end, making it more than three times the size of Hurricane Katrina
- **Storms pressure** was the lowest on record north of Cape Hatteras **at 945mb**
- **Storm timing** coincided almost exactly with astronomically high, high tide
- Storm surge combined with high tide created a **storm tide of over 11 feet** above NAVD88 at the Battery, highest water level on record (since 1856)

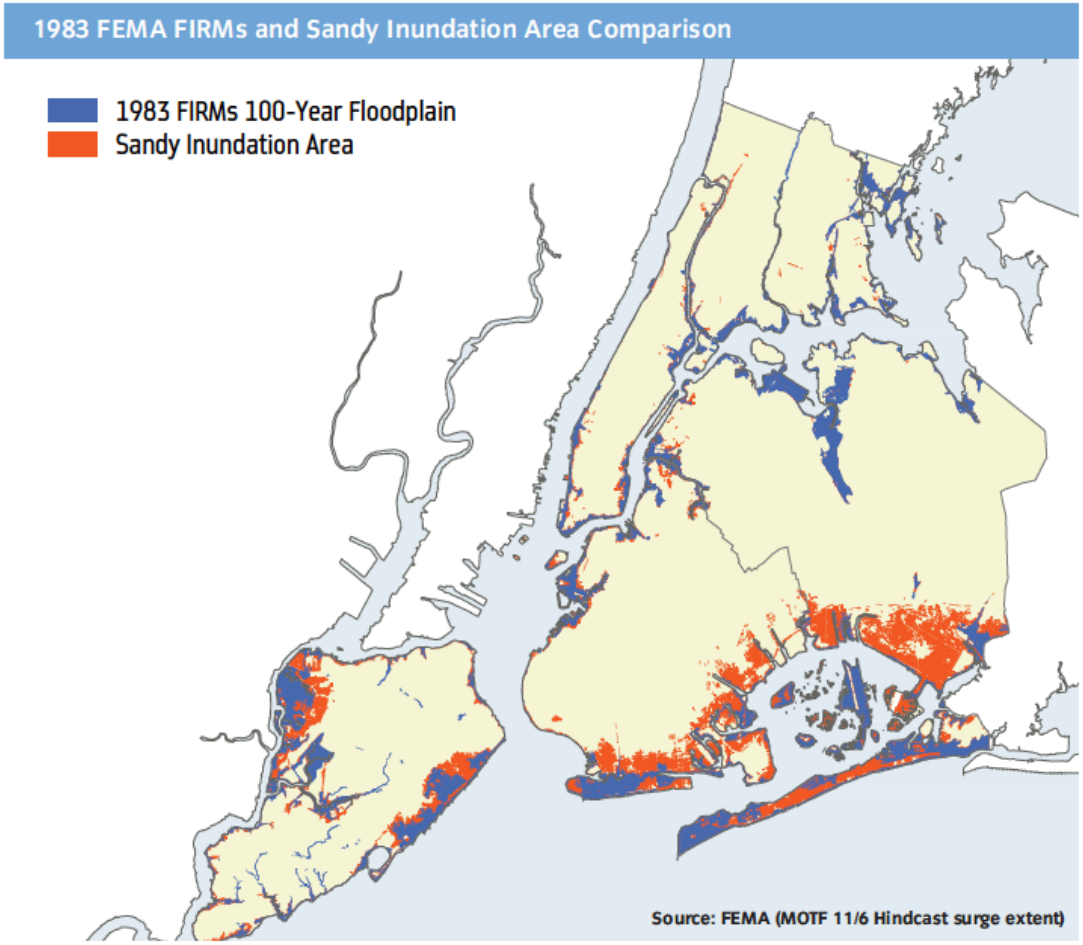






SIRR, 2013
CCSR, 2013

Comparing Flood Maps to Inundation Zone



FEMA 1983 100-year floodplain – ***~200,000 New Yorkers***

FEMA 2013 100-year floodplain – ***~400,000 New Yorkers***

FEMA 2013 100-year floodplain + NPCC2 90th percentile SLR projections for the 2050s – ***~800,000 New Yorkers***

Outdated FEMA maps significantly underestimated the current risk level

Source: SIRR, 2013

Hurricane Sandy
Links to Climate Change Science

- It is not possible to attribute any single extreme event such as Hurricane Sandy to climate change

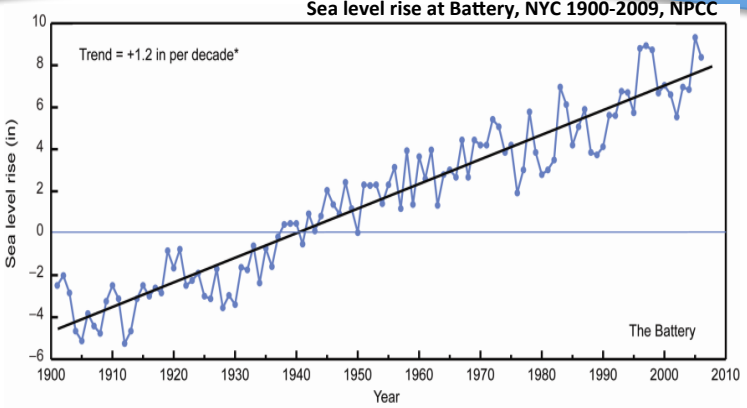
- Sea level rise already occurring in the New York City area (~1.1 feet since 1900), in part related to climate change, increased extent and magnitude of coastal flooding during the storm

- Intensity of severe hurricanes in the northern hemisphere Atlantic Basin appears to be on rise and may increase in future***

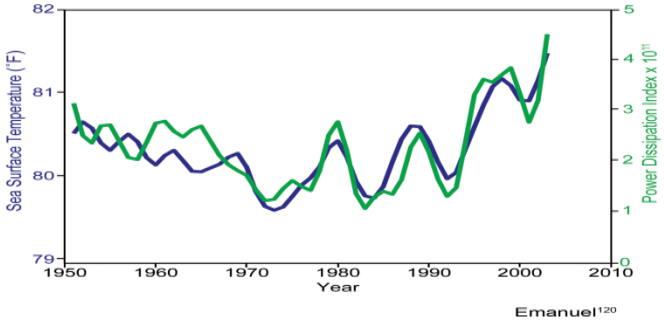
- Melting sea-ice may be changing pattern of jet stream, making westward-turning storm tracks more likely***

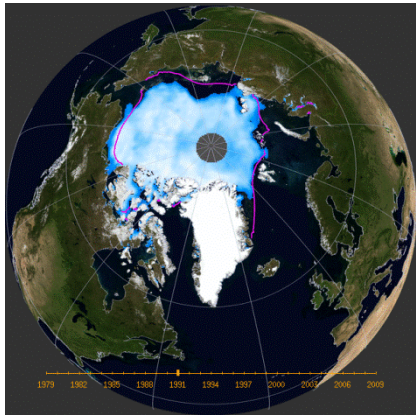
***Areas of active research

Sea level rise at Battery, NYC 1900-2009, NPCC



North Atlantic SSTs and Hurricane Power Dissipation Index 1950-2005, Emanuel , 2007

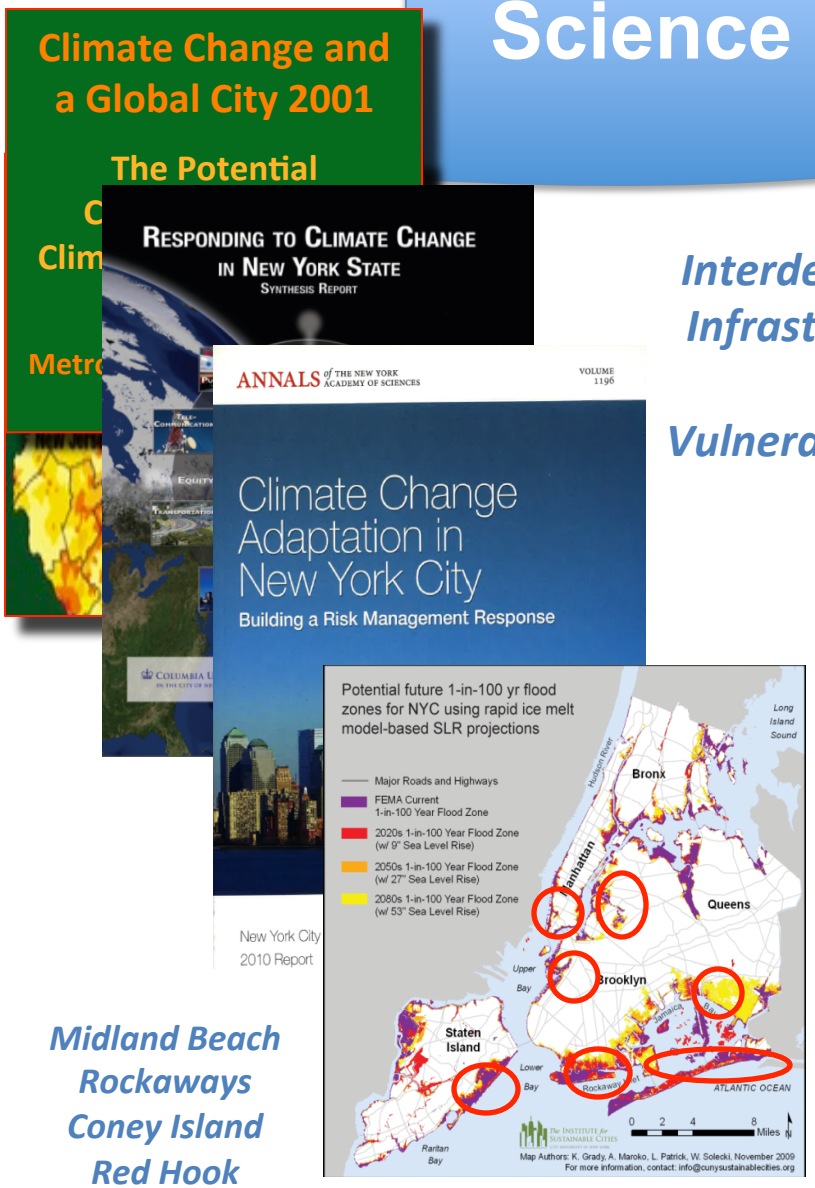




Median Minimum Sea Ice Extent 1979-2009

Source: CCSR, 2013

Science in Place . . . Science in Time

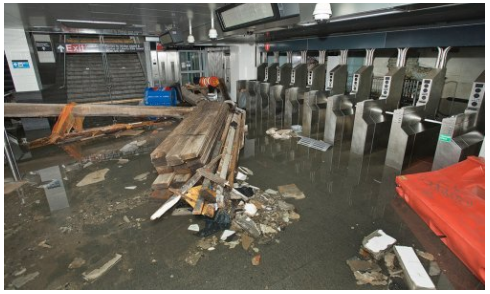


Interdependent Critical Infrastructure Systems and Vulnerable Communities

Areas hard-hit by Sandy

Midland Beach
Rockaways
Coney Island
Red Hook

South Ferry Subway Station



Beach erosion and boardwalk damage in the Rockaways

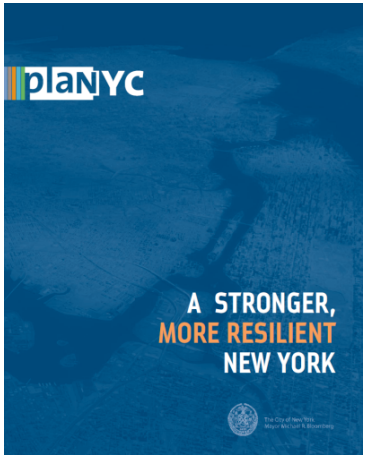
Extensive *power outages*

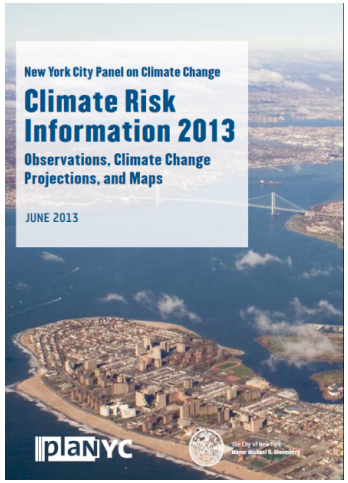
Many impacts forecast well in advance

Sources: CCSR, 2013, MTA, 2012

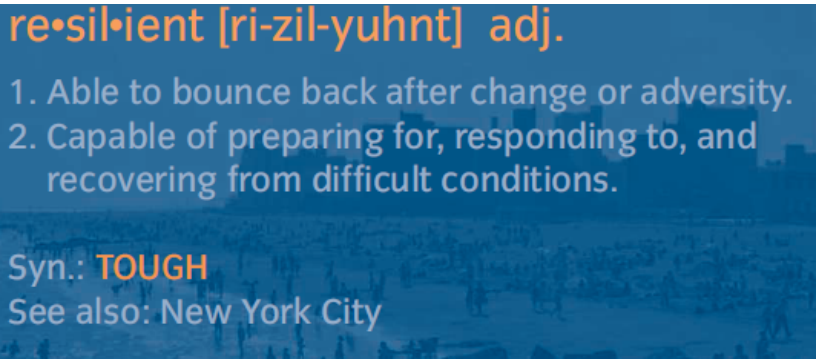
Second New York City Panel on Climate Change

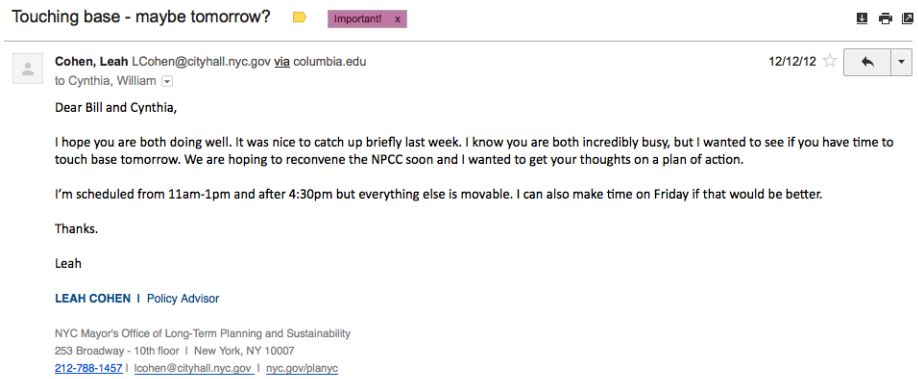
After Hurricane Sandy, Mayor Bloomberg re-convened the NPCC in January to provide updated climate risk information for the Special Initiative for Rebuilding and Resiliency (SIRR)





- The 2013 NPCC Climate Risk Information Report (CRI) provided new climate change projections and future coastal flood risk maps for New York City
- Both "A Stronger, More Resilient New York" and CRI reports released on June 11, 2013
- Full NPCC2 Report to be published in Fall 2014




Touching base - maybe tomorrow? Important! x

Cohen, Leah LCohen@cityhall.nyc.gov via columbia.edu 12/12/12
to Cynthia, William

Dear Bill and Cynthia,

I hope you are both doing well. It was nice to catch up briefly last week. I know you are both incredibly busy, but I wanted to see if you have time to touch base tomorrow. We are hoping to reconvene the NPCC soon and I wanted to get your thoughts on a plan of action.

I'm scheduled from 11am-1pm and after 4:30pm but everything else is movable. I can also make time on Friday if that would be better.

Thanks.

Leah

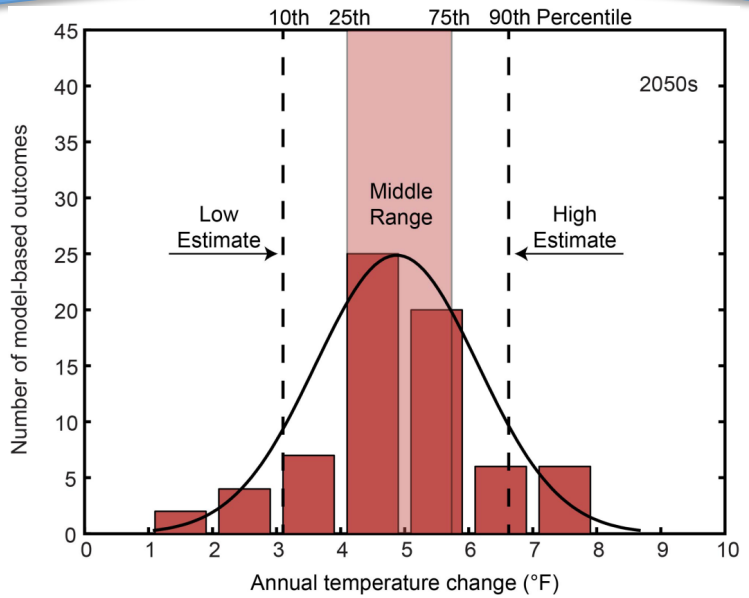
LEAH COHEN | Policy Advisor

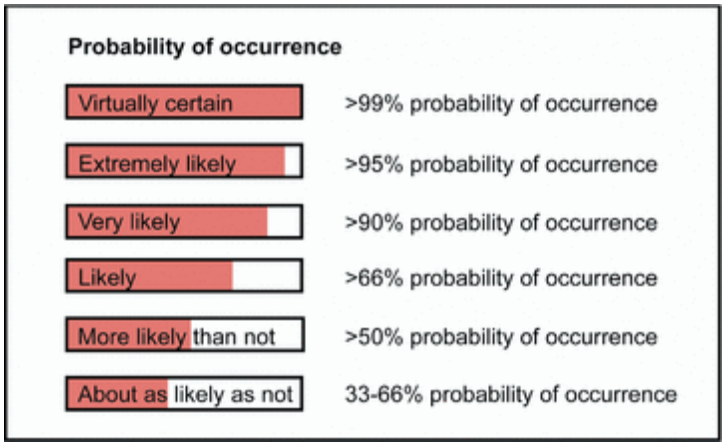
NYC Mayor's Office of Long-Term Planning and Sustainability
253 Broadway - 10th floor | New York, NY 10007
212-788-1457 | lcohen@cityhall.nyc.gov | nyc.gov/planyc

NPCC2 Uncertainty and Risk Management

Projections

- Designed with NYC stakeholders to facilitate risk-based decision-making
- Based on results from 35 global climate models and 2 scenarios of future greenhouse gas emissions
- Direction of change associated with likelihoods as defined by the IPCC
- Qualitative projections provided for some extreme events, e.g., number of intense hurricanes, based on scientific literature and expert judgment





Note: Model-based outcomes do not encompass the full range of possible futures

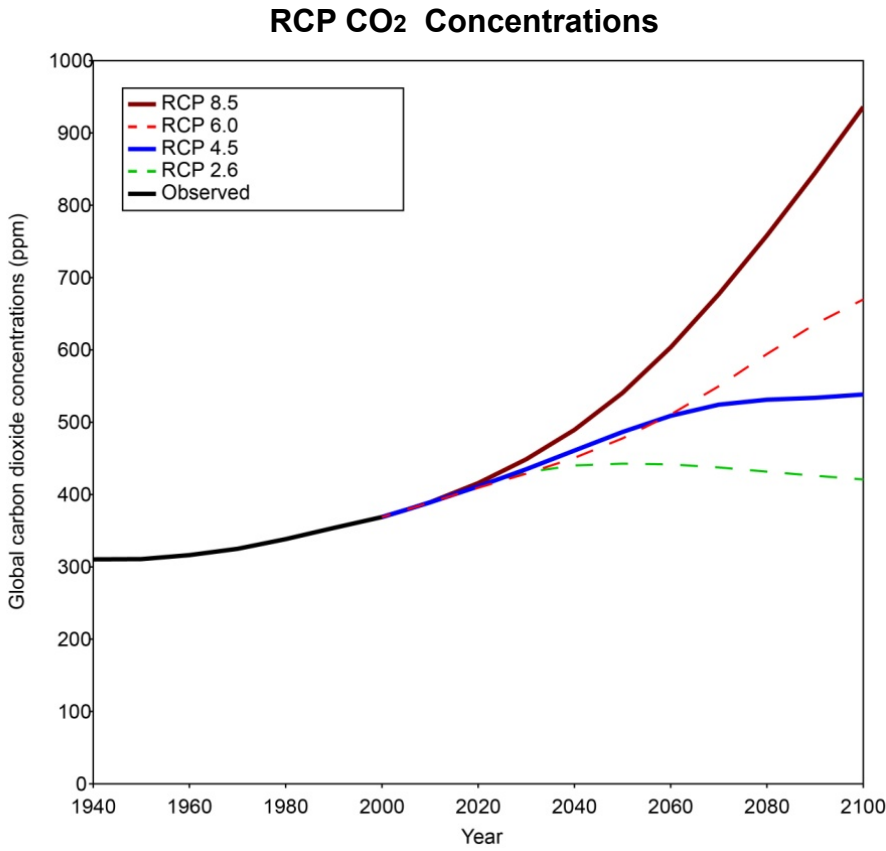
NPCC2 Climate Projection Methods
Temperature and Precipitation

- Quantitative projections based on global climate model simulations (CMIP5)
  - 35 global climate models (GCMs)
  - 2 representative concentration pathways (RCP4.5, RCP8.5)
  - Timeslices: 2020s, 2050s, 2080s, 2100
    - 30-year average centered around decade
  - 1 ensemble member per GCM

- Downscaling
  - Delta method (Wilby et al., 2004)
  - Extreme events mean monthly changes applied to historical daily data

- Single gridbox method: Compare observed and model values for current climate; test changes in neighboring gridboxes; define as 100-mile radius; provide caveats upfront (Horton et al., 2001 JAMC)

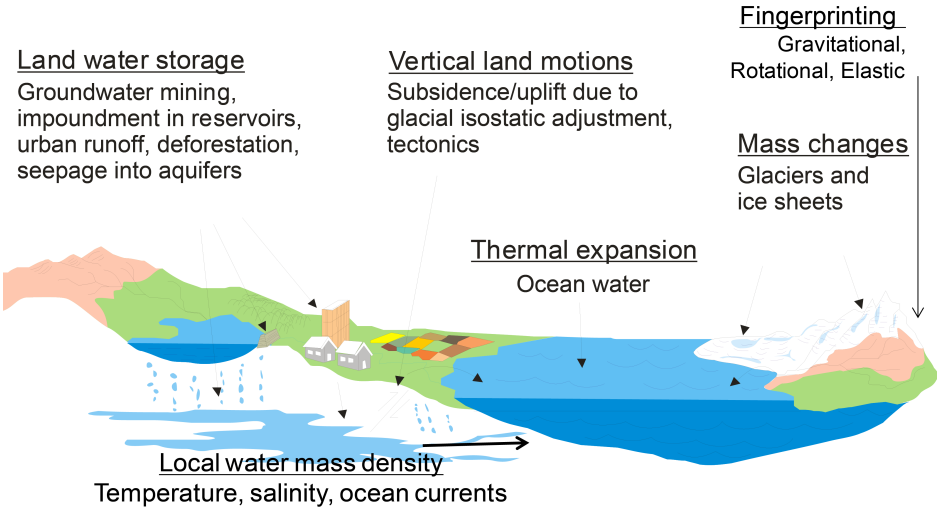
- Projections provided for mean annual changes and extreme events



Data from IIASA

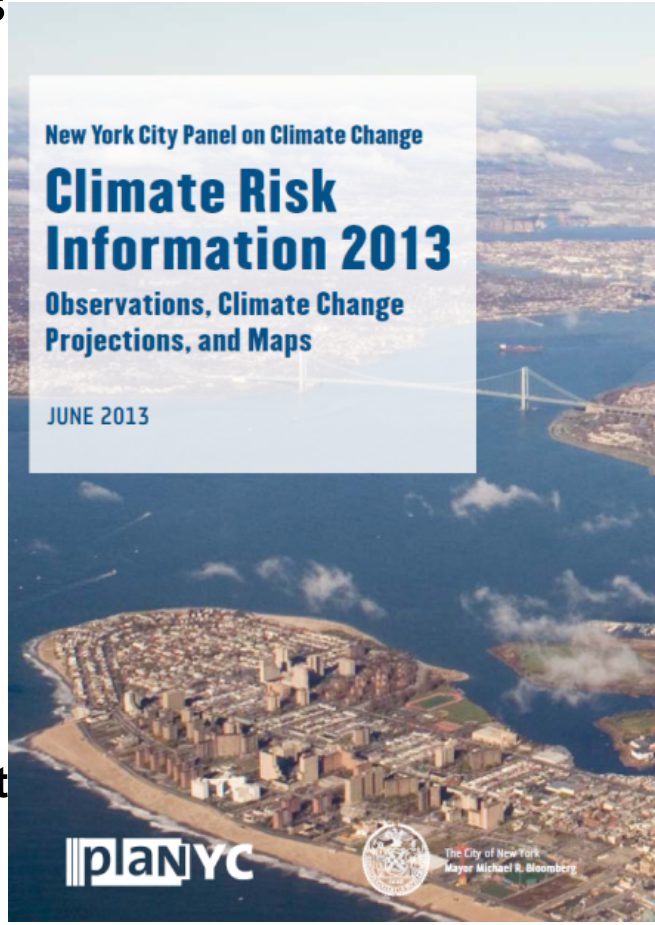
NPCC2 Climate Projection Methods
Sea Level Change

- Innovative, 6-component approach used to develop regional sea level rise projections
  - Model-based components based on CMIP5 Data (24 GCMs and 2 RCPs)
    - Thermal expansion (global)
    - Changes in dynamic ocean height (local)
  - Components based on literature review and expert analysis
    - Ice mass loss from ice sheets and glaciers and ice caps (global)
    - Gravitational, rotational, and isostatic "fingerprinting" (local)
    - Vertical land movements (GIA) (local)
    - Land water storage (global)
- Projections are taken as the sum of the 6 sea level components
  - Provided for 2020s, 2050s, 2080s, 2100
    - 10-year average centered around decade
  - Changes are relative to the 2000 to 2004 base period



Key Findings for Future Projected Changes

- Climate projections illustrate a broad-based acceleration of climate change in coming decades
- Show significant climate risks, especially heat waves, extreme precipitation events, and coastal flooding
- Valid for New York City ***and*** the metropolitan region
- By 2080s, projected changes include:
  - Annual **temperature increase** between **3.8°F** to **10.3°F**
  - Mean **precipitation** change between **+5 and +15 percent**
  - More likely than not increase in the **number of the most intense hurricanes in the North Atlantic Basin**.
  - Unknown how the **total number of tropical cyclones and nor'easters** will change in the North Atlantic Basin



Mean Annual Changes – Sea Level Rise

Sea Level Rise Baseline (2000 – 2004)	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
2020s	+ 2 in	+ 4 in to 8 in	+ 10 in
2050s	+ 8 in	+ 11 in to 21 in	+ 30 in
2080s	+ 13 in	+ 18 in to 39 in	+ 58 in
2100	+ 15 in	+ 22 in to 50 in	+ 75 in

Based on 24 GCMs and two Representative Concentration Pathways. Shown are the low-estimate (10th percentile), middle range (25th percentile to 75th percentile), and high-estimate (90th percentile).

Future Coastal Flood Heights and Recurrence Intervals at the Battery

2080s

	Current	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
Annual chance of today's 100-year flood height	1 percent	1.7 percent	2.0 to 5.4 percent	12.7 percent
Today's 1-in-100 yr flood height to recur, on average	Once every 100 years	~ once every 60 years	~ once every 20 to 50 years	~ once every 8 years
Flood heights associated with 100-year flood	11.3 ft	12.4 feet	12.8 to 14.6 feet	16.1 feet

Flood heights are derived by adding the sea level rise projections for the corresponding percentiles to the baseline values. Baseline flood heights heights associated with the 100-year flood are based on the FEMA still water elevations, i.e., without wave height. Flood heights elevations are referenced to the NAVD88 datum.

Tale of Two States and One City

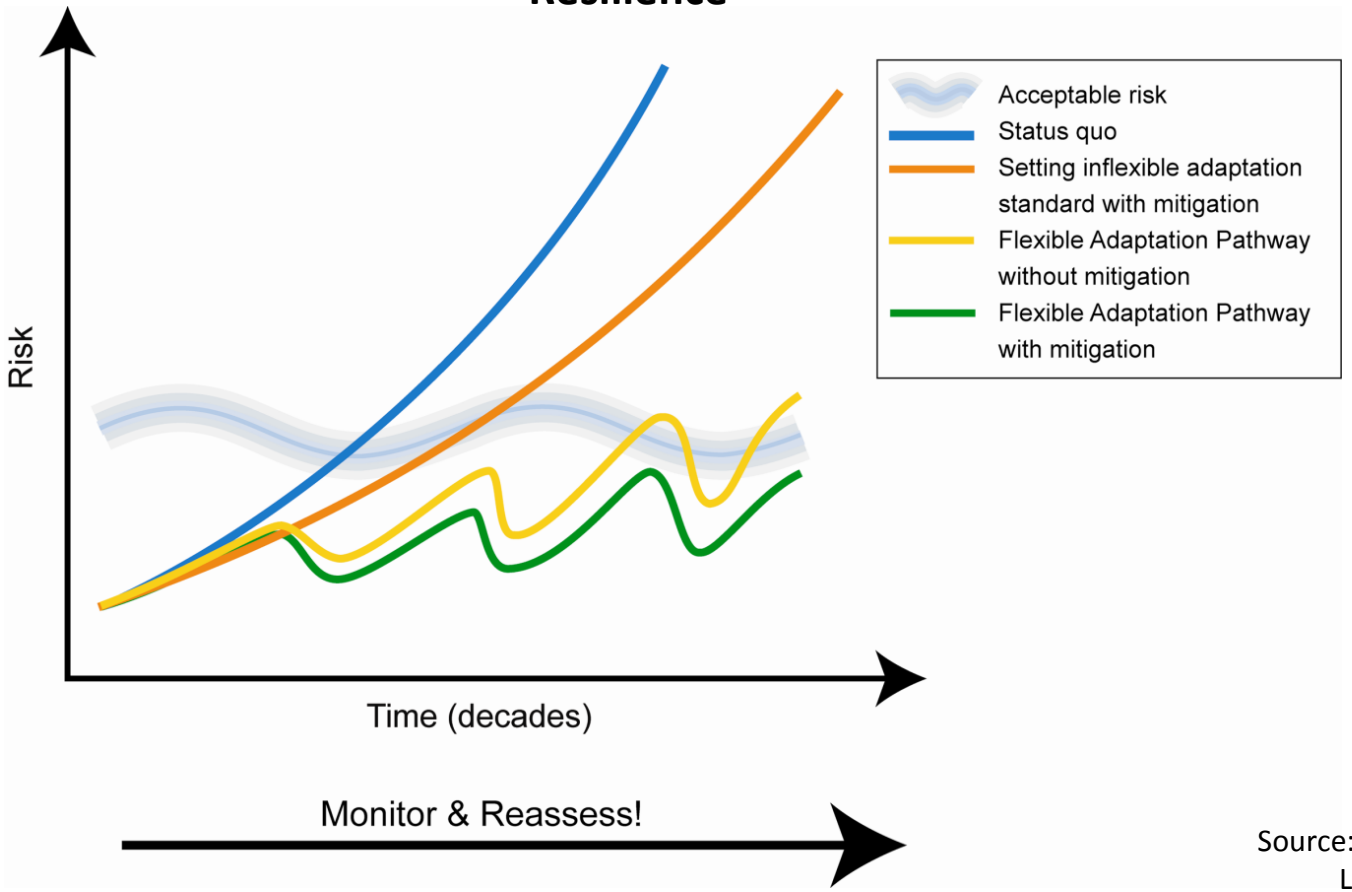
- Governor Cuomo of New York State established 2100 Commissions immediately following Sandy; recognized climate change as increasing risk.
- Governor Christie of New Jersey focused on rebuilding ‘as was;’ does not recognize climate change as increasing risk
- Mayor Bloomberg, Leader of C40 Large Cities Climate Summit, created $20 billion Resiliency and Rebuilding Plan, recognizes climate change as increasing risk
- US Congress required each entity to submit their own plans to receive appropriated funds; balkanized region

Risk Management
Flexible Adaptation Pathways

Climate change adaptation as a risk management issue

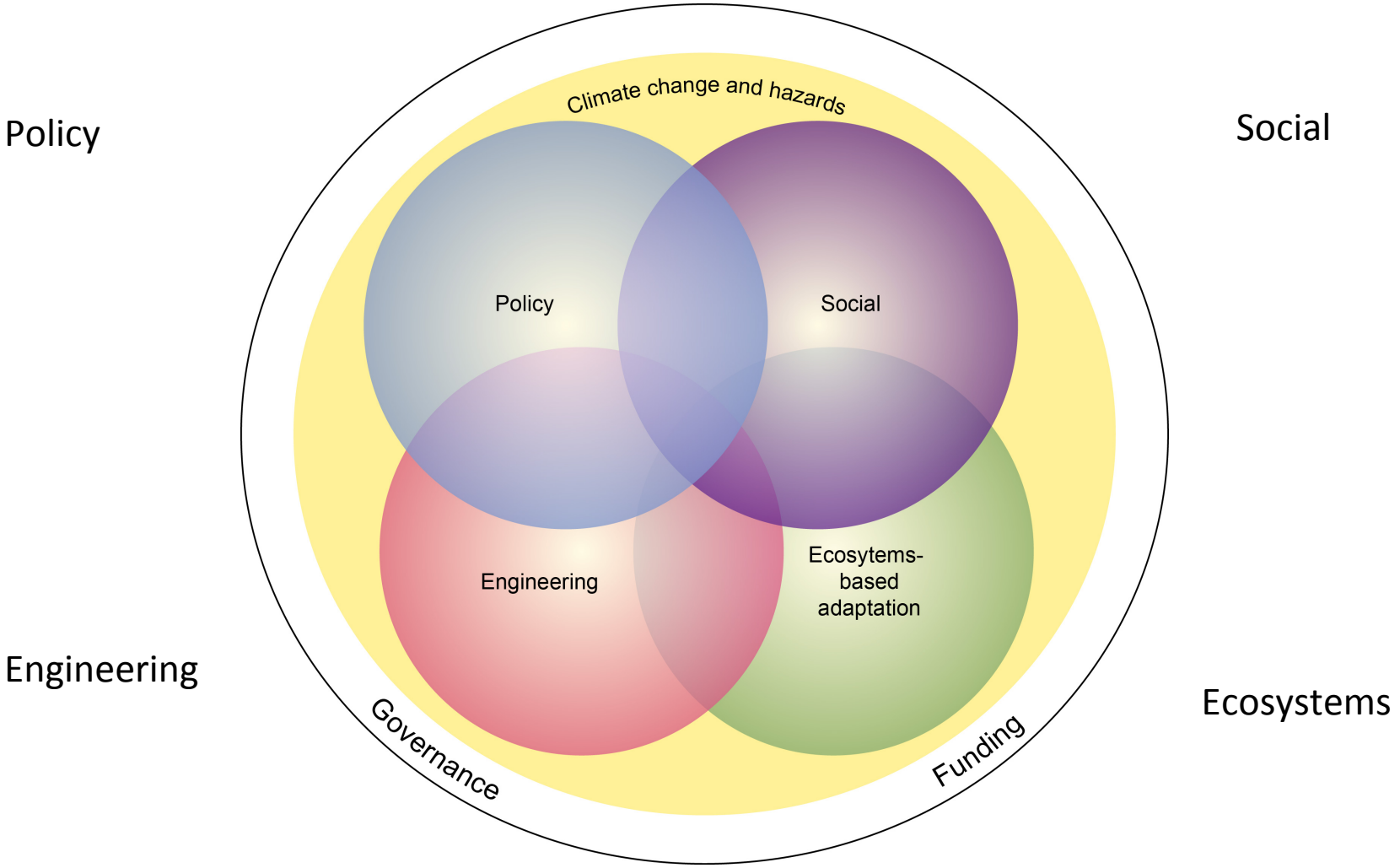
Flexible Adaptation Pathways as the response

Resilience



Source: Yohe and Leichencko NPCC, 2010

Portfolio Approach to Resilience Action

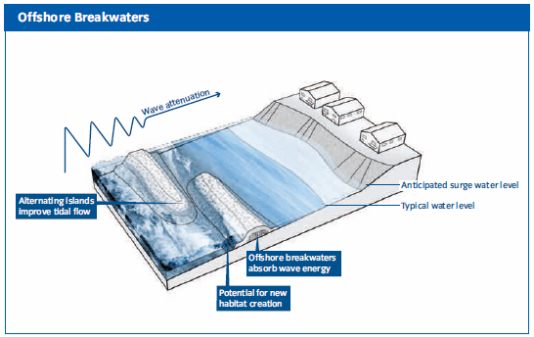


Policy, social, engineering, and ecosystems interact to respond to changing climate and coastal hazards. Overlapping areas illustrate opportunities for adaptation and resilience strategies that combine components of each domain.

NYC SIRR Key Actions for Coastal Protection

- **Increase coastal edge elevations**
  - The City will **increase the height of vulnerable coastal edges** with **beach nourishment** and other measures over time

- **Minimize upland wave zones**
  - The City will work to provide significant **attenuation of waves—that is, to knock down waves, or diminish their velocity**—both off and onshore, before they reach neighborhoods



- **Protect against storm surge**
  - The City will use **flood protection structures, such as floodwalls, levees, and local storm surge barriers** built, where possible, to the 100-year flood elevation with an additional allowance for future sea level rise

- **Improve coastal design**
  - The City will study **how natural areas and open space can be used to protect adjacent neighborhoods and maintain neighborhood quality of life**, and will work to **manage its own waterfront assets** more effectively

- **Governance**
  - Developing **partnerships** to improve permitting and study innovative coastal protections.

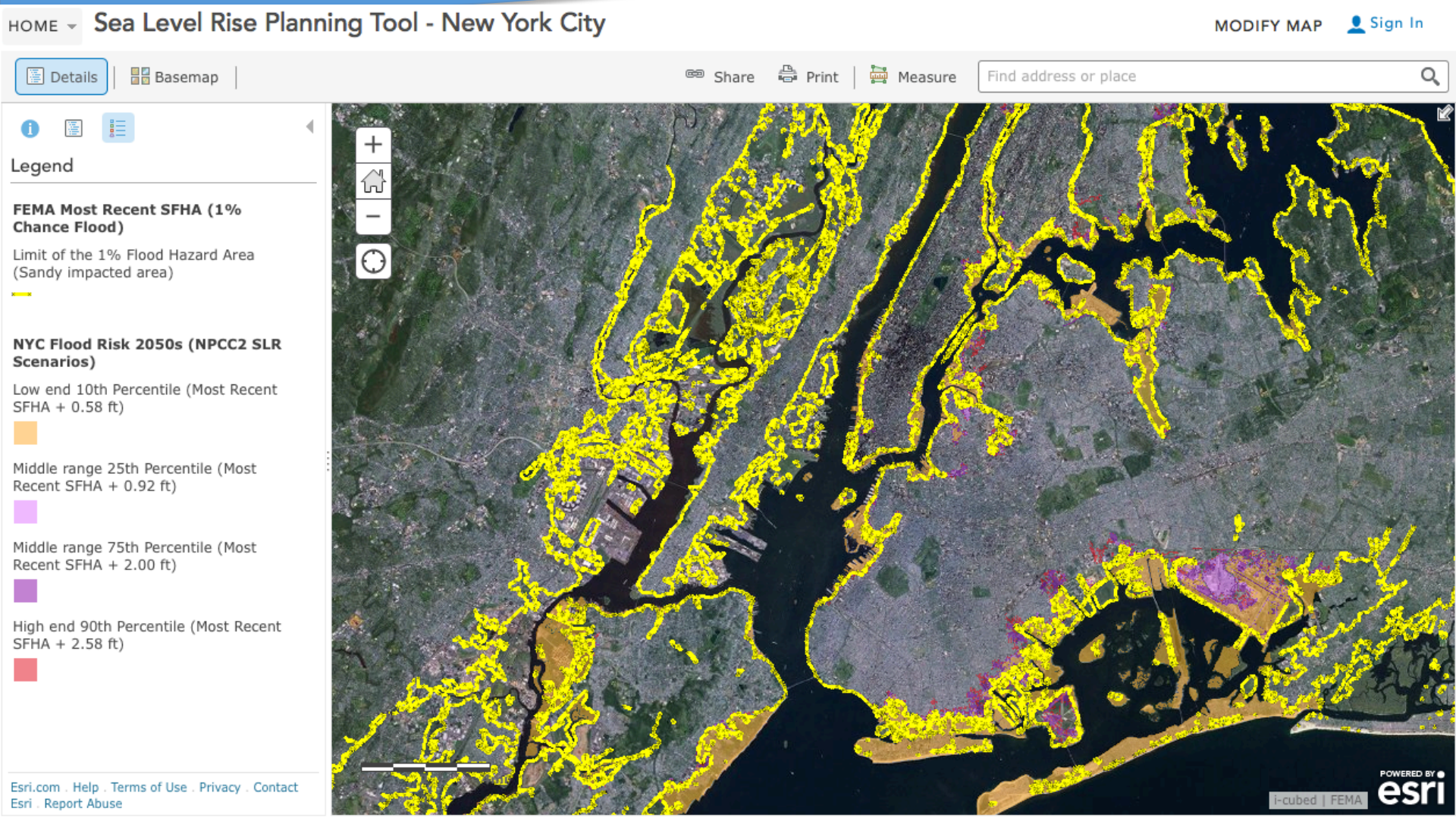
October, 2014 Update

5 of 37 coastal initiatives ***complete***

35 of 37 coastal initiatives ***in progress***

SIRR, 2013; City of New York, 2014

NOAA Coastal Map Tool



NPCC Projections added to FEMA 2013 flood hazard areas in NOAA Sea Level Rise Map

Source: NOAA;NPCC

Hurricane Sandy as Tipping Point

- Acceptable level of risk plummeted – People are demanding greater protection from coastal storm risks
- Investment and action were mobilized by New York City
- NYC SIRR, US Congressional Appropriations, and Rebuild by Design program are creating a transformative new development trajectory
- Explicit recognition of increasing risks due to climate change in coastal areas now thoroughly accepted in public discourse
- Major effect on coastal storm protection planning not only in New York City, but in New York State, nationally, and even internationally.

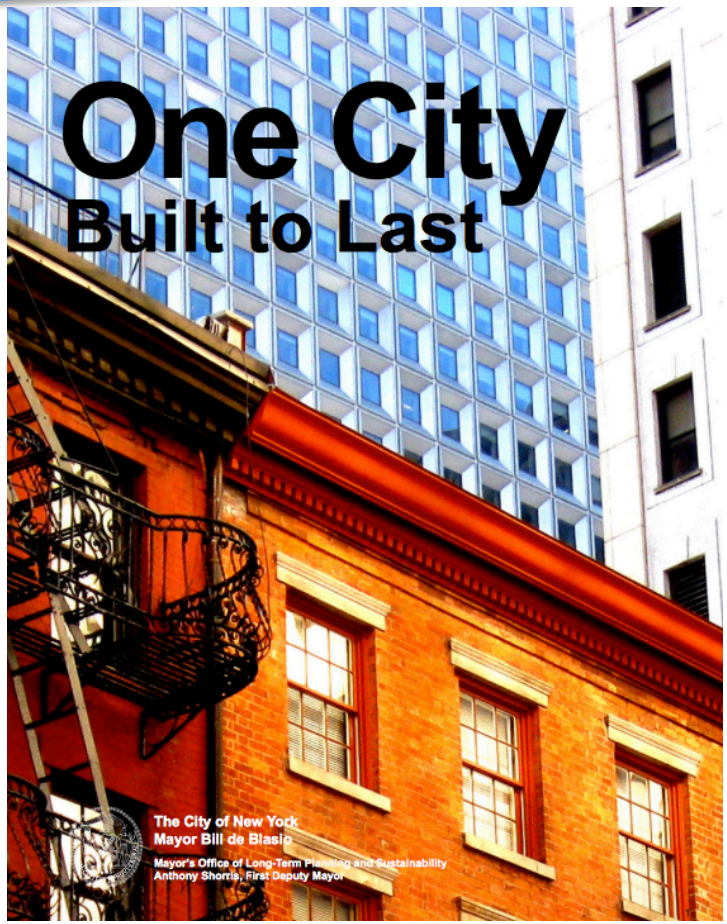
Hartwig Kremer, May, 2014

Factors → Leadership; Federal/State/Municipal alignment; Media hub . . .

Challenge is sustaining transformative trajectory . . .

Looking forward . . .

Bloomberg target – 30% reduction of 2005 levels by 2050



Mayor de Blasio has set ambitious target and timetable for GHG reduction and is reconvening NPCC, with emphasis on equity issues

City of New York, October 2014

"Global climate change is the challenge of our generation . . . New Yorkers will rise to the challenge. We will build on progress we have made to become more resilient to a changing climate and to mitigate the harmful greenhouse gas emissions that contribute to climate change. We are committing to reduce our emissions by 80 percent below 2005 levels by 2050, making us the largest city in the world to commit to this goal." Mayor De Blasio, Oct 2014

Temperature Change (2050s) and UCCRN Member Cities

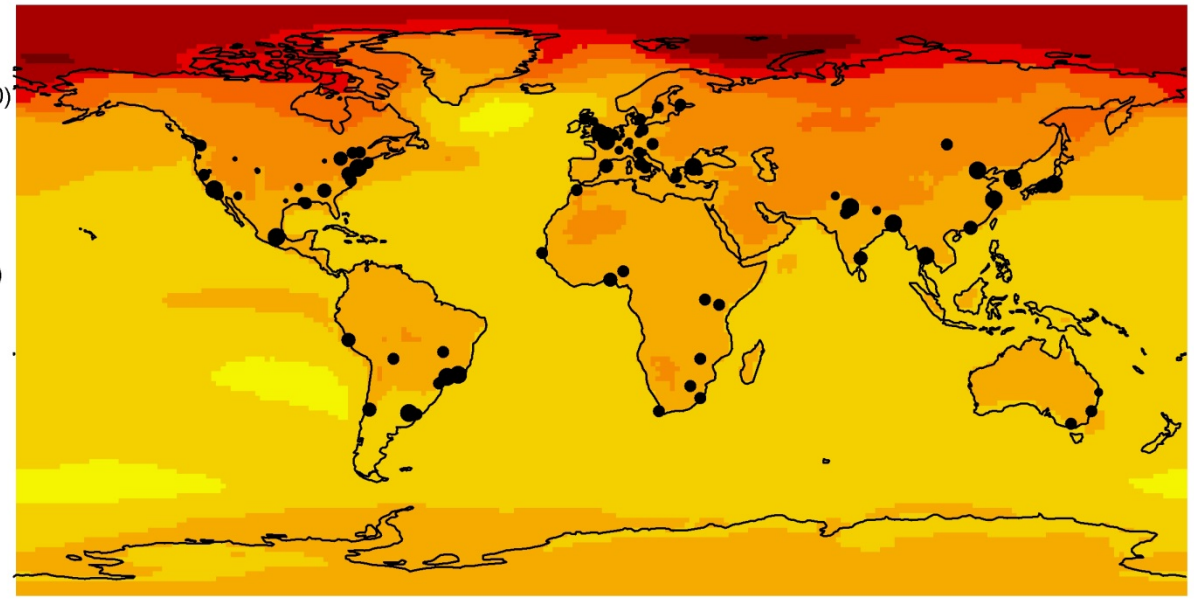
City Size

Population of Metro Area

- Small (<500,000)
- Intermediate (500,000-1,000,000)
- Big (1,000,000-5,000,000)
- Large (5,000,000-10,000,000)
- Mega (>10,000,000)

Temperature Change (Degrees C)

- 0 - .75
- .75 - 1.5
- 1.5 - 2.25
- 2.25 - 3
- 3 - 3.75
- 3.75 - 4.5
- 4.5 - 5.25
- >5.25



UCCRN Member Cities

Africa

Abuja
Cape Town
Dakar
Durban
Harare
Johannesburg
Kampala
Nairobi
Rabat
Setif
Sfax
Lagos

Asia

Bangkok
Beijing
Chennai
Delhi
Dhaka
Eskisehir
Hong Kong
Jaipur
Kathmandu
Kyoto
Nagoya
Ningbo
Sargodha
Seoul
Shanghai
Tokyo
Ulaanbaatar

Australia/Oceania

Gold Coast
Melbourne
Parkville
Sydney
Townsville
Wellington
Wembley

Europe

Aalborg
Athens
Barcelona
Berlin
Bonn
Bristol
Brussels
Copenhagen
Enschede
Exeter
Freiburg
Geneva
Glasgow
Groningen
Helsinki
Istanbul
Kokkola
Leipzig
London
Luxembourg
Naples
Newcastle upon Tyne
Oxford
Paris
Peterborough
Planken
Potsdam
Rome
Stockholm
Stuttgart
Tallinn
Trieste
Venice
Vienna

North America

Amherst
Atlanta
Aurora
Baton Rouge
Boston
Boulder
Cambridge
College Park
College Station
East Lansing
Englewood
Eugene
Guelph
Hauppauge
Idaho Falls
Kingston
Los Altos
Los Angeles
Martinez
Mexico City
Montreal
Mountain View
New Haven
New Orleans
New York
Norfolk
North Little Rock
Nyack
Ottawa
Reno
Sacramento
Saint Catherines
San Diego
Seattle
Toronto
Tucson
Washington DC
Yardley

South America

Brasilia
Buenos Aires
Concón
Curitiba
Lima
Montevideo
Rio de Janeiro
Santa Cruz
Santiago
Sao Paulo

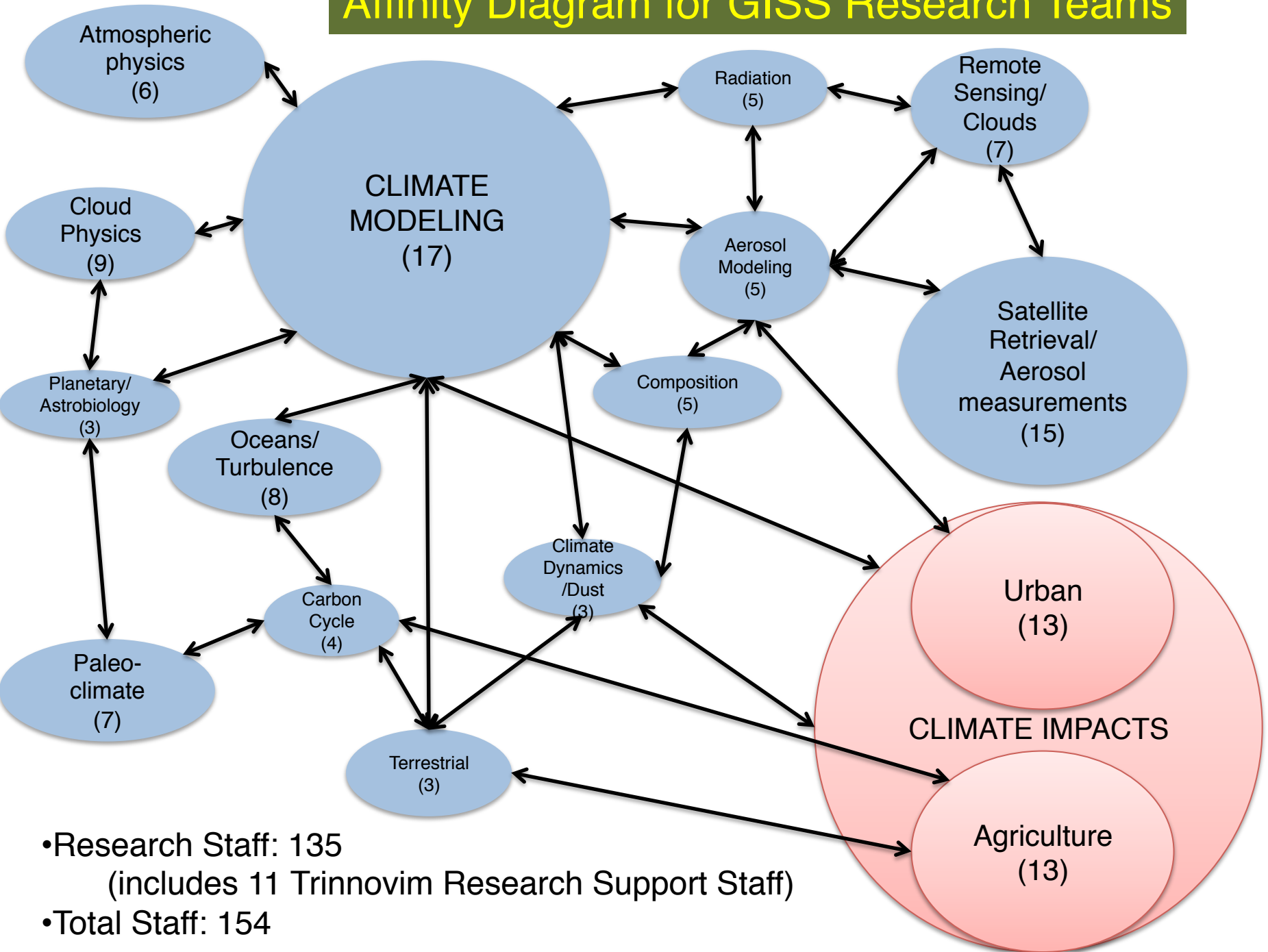
*colors represent mean annual temperature change for a mid-range scenario (RCP4.5) from CMIP5 models (2040-2069 average minus 1971-2000 average).

(35 CMIP5 models)

References and Links

- Consortium for Climate Risk in the Urban Northeast (www.ccrun.org)
- NYSERDA ClimAID (www.nyserda.ny.gov/climaid)
- New York City Panel on Climate Change report available online at (www.nyas.org)
- Urban Climate Change Research Network (www.uccrn.org)

Affinity Diagram for GISS Research Teams



- Research Staff: 135
  (includes 11 Trinnovim Research Support Staff)
- Total Staff: 154